OPTICAL LOW COHERENCE REFLECTOMETRY : NEW DEVELOPMENTS,

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Introduction

Optical low-coherence reflectometry (OLCR) is a technique based on interferometry which is design to detect and localize reflectors[1]. This technique has been widely investigated. It is now possible to scan samples with high spatial resolution and constant high speed [2]. However, the envelopes of the interferograms are usually considered as the essential part of the measurement results.

We report here on an OLCR experimental set-up designed to obtain simultaneously high accuracy, high stability and high reproducibility on the location of propagation defects along optical waveguides. One of our objectives is to get informations of the phase in the Fourier transform.We firstly describe the fringe counting system which is used to measure the length of the reflectometer reference arm and to trigger the interferograms sampling. We secondly describe the third interferometer coupled to a white light source whose response starts the fringe counting. We use our system as a spectrometer to test the stability and the reproducibility. Sources with very different broad spectra are investigated. One of them is filtered through a Fibre Bragg grating sample under stress and the results are plotted against the stress conditions.

Experimental set-up

The basic functions operate from three different Michelson interferometers (Fig. 1):

1. the reflectometer : the waveguide (or sample under test) is part of the test arm
2. the fringe counting for accurate length measurement: the light source coupled to the interferometer is a frequency stabilised HeNe 630 nm laser and the signal is sampled every 80nm
3. the high resolution "single" trigger signal is obtained at the output of an interferometer around the white light fringe: the light source is a broad band superluminescent LED.

These three interferometers are coupled via a moving carriage as it can be seen on figure 1, so that the variations of the red and infrared optical pathlengths are correlated.
Visible and infrared interferograms are detected respectively by Si and InGaAs PIN diodes connected to low noise amplifiers. The red fringe couting output is transformed into a TTL signal which samples the infrared interferograms before the data acquisition..

The white light interferograms obtained at the output of the third interferometer connected to the broadband superluminescent LED have a central fringe width less than .85 μm. This gives a very precise reference for the position of the moving carriage.

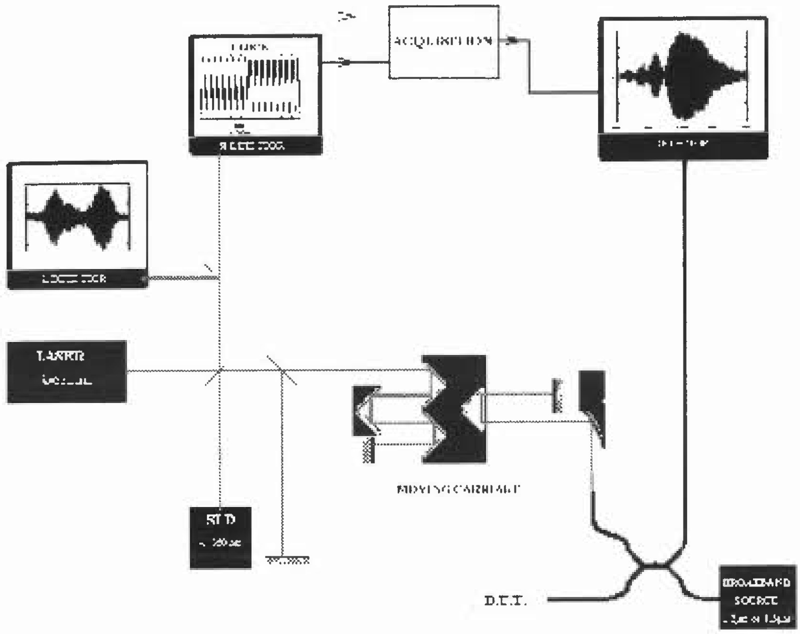

fig1 : experimental set-up

The reflectometer center part is a broadband singlemode coupler. The sources we mostly use are 1.3 μm and 1.5μm LEDs . The reference arm is in free space : the light emerging from the coupler is collimated by reflection on a parabolic gold mirror to avoid chromatic aberrations and dispersion, and then directed to a corner cube fixed on the moving carriage. The cornercube reflects it to the fixed plane gold mirror (see figure 1). The device under test is inserted in or coupled to the test arm.

Commercially available OLCR provide limited informations derived from the envelop of the interference patterns. They only detect and give the position of reflecting surfaces from the interferogram signals. When a more accurate description of the reflector is needed such as properties bound to the phase, the entire information contained into the signal must be taken into account [3-6]. The informations on the phase are also contained into the fringes : if x is the displacement of the moving carriage and σ the opposite of the wavelength, the detected intensity can be written as

$$\mathrm{I} = \mathrm{I}_1 + \mathrm{I}_2 + \mathrm{TF}\left[\mathrm{S}(\sigma) D(\sigma) r(\sigma)\right]$$

where I_1 and I_2 are respectively the intensity in the reference and test arm.

The interference term is the Fourier Transform of the product of three functions :

- $S(\sigma) = |\rho(\sigma)|^2$ is the source spectra, σ is the inverse of the wavelength
- $D(\sigma) = e^{-i\beta(\sigma)\sigma L}$ describes the propagation (and the dispersion) of the wave between the entrance of the component and the reflecting surface.
- $r(\sigma)$ is the reflection coefficient. It depends on the nature• and the form of the reflecting surface.

It is then possible, using inverse Fourier Transform, to measure the dispersion inside the device under test and the spectral signature of the reflectors.

Experimental results

We observed experimentally that the mechanical stability of our system is good : for a one meter displacement of a moving carriage the variation of the continuous signal is about 10%. But its main advantage lies in the linear sampling which leads to a perfect reproducibility of the experiments. An example of the degree of reproducibility is given on figure 3 : spectra of the source taken at different times are shown, with a fibre ended by a mirror in the test arm.

Such a device can then be used as a spectrometer with a good resolution (about 30pm). In order to test this sensibility, the light reflected from a fibre bragg grating (FBG) has been used as a source for the reflectometer. This source is a sharp peak of 300pm width, centred at 1.55µm, as shown on figure 3 where is plotted a measured spectrum of the light reflected by the FBG.

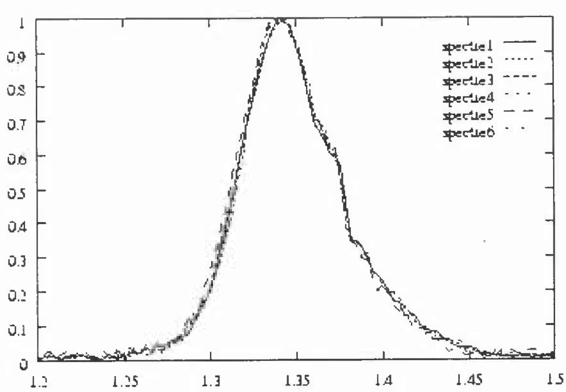

fig2 : *LED spectra*

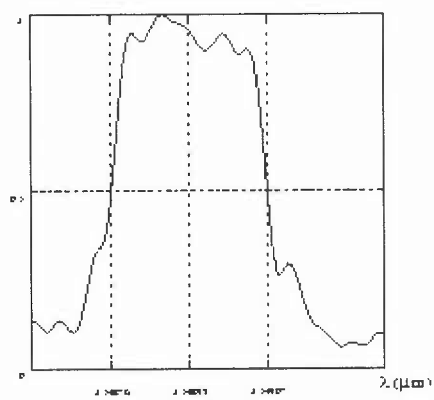

fig3 : *spectrum of FBG reflected light*

We use the FBG as a source filter for the following reason : the centre wavelength (or Bragg wavelength) of the light reflected by the FBG depends on the period of the grating. So when the fibre is constrained, the variation of the grating pitch induces a variation of the Bragg wavelength, which order of magnitude is 1pm for 1µε strain.

In our experiment the FBG is fixed on a plate. Stress are applied to the plate which undergoes strains ranging from 50µε to 300µε.We then observe, as expected, a linear displacement of the Bragg wavelength. This can be seen on the figure 4, where the Bragg wavelength is plotted versus the strain.

We find a variation of almost 1.1pm/µε which is in a very good agreement with the values found in the litterature[7]..

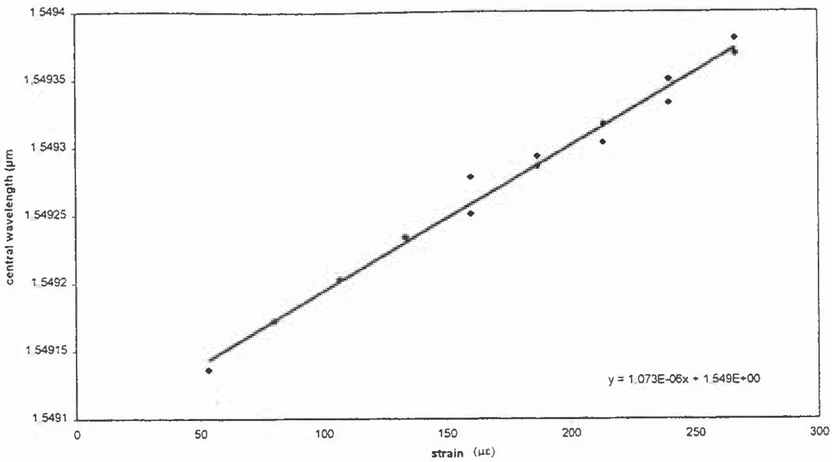

fig4 : *Bragg wavelength versus strain*

Conclusion

This device presents already a good reproducibility and a high sensitivity. The calibration tests have shown its efficiency.

The next step will be to test the system in the classical OLCR configuration to get full information on the phase. This will allow an accurate resolution in the localization of defects and a better understanding of their nature.

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